DOCUMENT RESUME

ED 265 404 CE 043 437

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TITLE Technology and the Goals of Quality Education in Pennsylvania.
PUB DATE 5 Nov 82
NOTE 61p.; Paper presented at the Annual Conference of the Pennsylvania Industrial Arts Association (30th, Camp Hill, PA, November 4-6, 1982).
PUB TYPE Viewpoints (120) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS Classroom Techniques; Curriculum; Educational Needs; Educational Objectives; *Industrial Arts; Laboratory Procedures; Needs Assessment; *Program Content; Program Improvement; Secondary Education; *Statewide Planning; Teacher Workshops; Technical Education; *Technological Advancement; *Technological Literacy; Technology; *Trade and Industrial Education
IDENTIFIERS *Pennsylvania

ABSTRACT

This workshop presentation was developed to assist Pennsylvania industrial arts teachers in developing and teaching a curriculum in technology and technological literacy that meets the 12 Pennsylvania goals for attaining quality education that were established in 1979. Designed to explain the basis for the study of technology in public school technology programs, the presentation addresses the following topics: the impact of technology on society; the evolution of technological systems (production, transportation, and communication and information systems); the nature of technical means (knowledge of society, knowledge and technical means, and intellectual factors); the relationship between technology and science; the importance of technological literacy and the nature of technological systems; the need to study technology; and a curriculum structure for technology education. (MN)

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ED265404

Pennsylvania Industrial Arts Association
30th Annual Conference

Penn Harris Motel
Camp Hill, Pennsylvania

November 4-6, 1982

Conference Theme: Quality Education and Industrial Arts

General Session Speech, November 5, 1982, 10:30 A.M.:

"Technology and the Goals of Quality Education in Pennsylvania"

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Technology and the Goals of Quality Education in Pennsylvania

Paul W. DeVore

In March 1979 the State Board of Education of the Commonwealth of Pennsylvania established twelve goals to faster achievement of a quality education. The twelve goals are: communication skills, mathematics, self-esteem, analytical thinking, understanding others, citizenship, arts and the humanities, science and technology, work, family living, health, and environment. Each of the goals is described in the proposed revision of Chapter 5, Curriculum Regulations, by a brief statement and a series of program requirements to aid educators in establishing programs to meet the goals.

In the field of industrial arts Dr. Thomas Soyster, chairperson of the Curriculum Committee, is coordinator of the task force charged with developing a program description booklet for industrial arts that illustrates the relationship of industrial arts to the twelve Goals of Quality Education.

To assist the industrial arts profession in this task we have prepared for presentation today a series of topics on the study of technology. Essentially

there are two parts to the program. The first part will explore the basis for the study of technology in the public schools and the second part will provide workshops on how to teach about technology in your classrooms and laboratories.

The recognition by the Pennsylvania State Board of Education of the importance of the study of technology by all students is truly a significant education happening. Implementation of the goal by the industrial arts profession and others will be a major undertaking primarily because technology is so little understood and even misunderstood and has been absent so long from the curricula of public schools. The origin of this tragedy began with Plato in his separation of contemplation from action and the world of technical things. Today, fortunately, many people are beginning to recognize the error of Plato and others and are more and more, at all levels of education, including the study of technology in the curricula. The reasons are obvious. In general, people know little about the creation, use and behavior of the technical means that affect their lives and the long-term future of human civilization. Those who have studied the evolution of our technological society can contribute to our understanding and help us in our efforts to design appropriate

and quality education programs for the youth of today and tomorrow.

Technology and Society

Today in the Western world, and in an increasing number of areas of the non-Western world, the dominant characteristic of the society is its technical and industrial nature. While two centuries ago societies were predominantly focused on some form of food gathering, today this factor occupies fewer and fewer people. The great majority are involved in a vast technical apparatus in their work, private lives, and leisure. Yet, it becomes increasingly obvious that humankind today is only beginning the journey in a world which will become more technological, not less.

Humankind's creative endeavors in the technologies have greatly increased the interdependence of all people. Improved technics in agriculture and health care have altered, in an exponential way, the population of the earth, placing greater demands on available material resources and the natural environment. In a similar manner, improved means of information dissemination through the development of the means of mass-communication such as newspapers, radio, motion pictures and, more recently, television have raised the level of awareness

of millions of people throughout the world to the potential of a better life for themselves, their families, and their offspring through the creation of new means of production, communication, and transportation. These new levels of consciousness bring forth not only problems of resource distribution and utilization, but, also, political questions related to who shall govern and how those who do govern shall function with respect to the larger questions affecting their own people and the global society as well.

Technology has always been a potentially disruptive force within a society. However, the character and potential of the technical means have been altered greatly in the last two centuries, particularly since the invention, innovation, and development of computers and microprocessors, two examples of new technical means that have altered the entire nature of society within a span of decades. These and other changes in the technological nature of society have increased the level of awareness of many and created, in some, a genuine state of anxiety brought about by the pace and rate of change, the fear of becoming useless, the increasing alienation of people from the artifacts which dominate their day-to-day life, and the uncertainty about how best to arrive at ethical judgments

related to the human condition. Questions never raised before became critical issues by the middle of the twentieth century. How many people should there be in the world? Who should decide? Of the total resources available, how shall they be distributed among the people of the world?

Those who have studied the evolution of civilization have found that truly significant changes in human potential and the order of things seem to come about with the creation of either: (1) a more stable and abundant food supply; (2) new and better materials; (3) alternative forms of energy supply and the means of conversion; (4) a more efficient means to collect, store, transmit and process information; or (5) a better means to control tools, machines and technical systems.

The lateen sail is an example of one of the earliest and more significant technical developments relating to control. It enabled mariners to control their boats and sail against the wind. The lateen sail, the stern post rudder and the magnetic compass, together with information about the stars, provided the technical means and information necessary to circumnavigate the globe and engage in regularly scheduled commerce throughout the year.

Today, new forms of energy and materials, information about the orbits of the planets, and control (in the form of inertial navigation and the computer) have provided the means to reach the moon and the stars beyond and, in the process, have changed our perceptions of who we are and what the future may bring. These and other technological developments have altered the reservoir of technical means from which our future will emerge.

This reservoir contains the means for another technological revolution. We are in the beginning stages. It is a revolution based on information and control and the significant component is the integrated circuit chip which has made possible the microprocessor--a computer on a chip. Today, there are over 300,000 personal computers being used in businesses, industry, schools and offices. The predictions are that continued development of microelectronics and their offspring, microprocessors, will bring about changes in every aspect of society throughout the world.

A Continuing Evolution

Beginning in the late 1940s, significant changes took place in the structure of the world economic systems. These changes took place following advances

in several technical systems. These included:

1. Advances in air and sea transportation which decreased costs and travel time between continents.
2. Improvements in communication and information systems including radio, telephone, television, the computer, and microelectronics.
3. Unprecedented innovations in new products and new production procedures which reduced costs.

These developments set the stage for the expansion of new markets and the spread of technical means on a global scale.

Three major consequences accompanied the advances in transportation, communication, and production systems. These included an increased interdependence among national economies, an enhanced role of technological innovation in economic growth, and a rapid expansion of global corporations designed to take advantage of the potential of the new technologies (Gilpin, p. 441).

The trend toward global interdependence and increased technological innovation continues. The new technologies have enabled the establishment of transnational corporations by providing improved means of transportation and

communication. They have also provided new products for world markets manufactured by cybernated systems of production.

Production Systems

The evolution of global systems was based on new developments in transportation and communication, and particularly on a new rationality about the organization of production--where processes are linked to processes, plants to plants, firms to firms, and industries to industries in a global system.

The material base of production was altered with new knowledge about the structure of matter, chemical and physical, in the transmutation of an ever widening range of raw materials. The new materials greatly expanded the product potential and initiated improvements of products already in service. The second major change impacting on the nature of production processes was the development of highly precise and agreed-upon standards and specifications for products, procedures, quality of materials, and the characteristics of tools, machines, and product components. These have been fundamental to the functioning of an integrated global system of technology. The third essential factor in the evolution of global production systems was control, implemented

through the design, implementation, and integration of cybernetic systems based on developments in electronics, machine design, and computers.

There were essentially three phases in the evolution of control systems for production. These included the creation of techniques and equipment for the automatic handling of materials, early examples of which include the Chicago meat-packing houses and Henry Ford's assembly line. Next came the integration of automatic handling equipment with automatic production or processing equipment. Finally, the means were created to control the entire system with computers programmed to accept and process information about the on-going production. This information was then sent to the electronic controls of given machines to initiate correcting action, thereby maintaining production quality continuously throughout the production cycle.

Transportation Systems

Mass production presupposes mass consumption which means that a high production operation must have a means to distribute the outputs or products. Mass production also presupposes an adequate supply of inputs, raw materials which require a reliable delivery system. A fully cybernated production system, therefore, relies not only on in-plant transportation systems in the form

of conveyers and other material and product handling and transfer devices but also on transportation systems external to the plant.

There have been major changes throughout the world in transportation systems since the 1940s. In many ways these changes were greater than any changes since the advent of steam-propelled rail and marine transportation. One of the changes was conceptual--the realization that goods and people could be moved more effectively and efficiently through unified and integrated systems. Concurrent with the unification and integration of systems was the creation of the means to establish systems through innovations and inventions in the technical elements including advances in propulsion, guidance, control, suspension, and structural components for all environmental modes.

Essential to these developments were the design and implementation of management systems capable of functioning in a new conceptual mode with respect to the scheduling and routing of transport movements.

Technical developments included the adoption of the diesel engine to rail and truck transportation and the turbine engine to air transportation. These developments, among others, greatly improved the

efficiency and reliability of transportation as part of the total system. Combined with the development of high-speed, limited access, multilane highway systems, electronic navigation, containerized freight, unit trains, high-capacity aircraft, supertankers, pipelines, and improved canals and seaways were developments in communication and information systems which enabled the establishment of computerized traffic control, scheduling, routing, and maintenance procedures, among others.

Communication and Information Systems

In the mid-1800s, the rudiments of a new technology of information were born. These established the base for processing information that may prove to be as significant in the history of civilization as were the mechanical and heat energy developments which served as the foundation for industrialization in the eighteenth and nineteenth centuries.

Many of the components of information systems have been well known in their external physical forms. The telephone, for example, first developed in the mid-1800s by Alexander Graham Bell and patented in 1876, greatly expanded the potential of disseminating information beyond the capability of the electric telegraph. Other

developments, using electrical or radiant energy to process or transmit information, included the phonograph and radio, two developments which introduced new means for storing and transmitting auditory information. The processing of visual information was initiated with developments such as photography and expanded by developments in motion pictures, the cathode ray tube, and television.

The major breakthroughs, however, and the developments which form the core of the information-systems revolution of the last quarter of the twentieth century were the creation of programmable electronic computers and the invention of the transistor in the late 1940s. The computer provided the capability to manipulate and transform information; the transistor, the potential for small and reliable sensing and control devices so essential to the high-speed automatic collection and processing of information.

The fusing of computer technology and communication technology gave birth to information-systems technology, a new technology which has altered and will continue to alter the very existence of humankind. By the late 1970s the number of computers installed in business, industrial, educational, and governmental organizations had far exceeded the most optimistic of earlier predictions

growing from about 1000 large-scale computers in the mid-1950s to over 220,000 in the mid-1970s. By 1977 the shipment of digital computing machines exceeded 1,300,000.

Key events in electronics at the core of the surge in information system capability were innovations in microelectronics and microprocessors. Microelectronics made possible integrated circuits which reduced greatly the size and power requirements of electronic equipment. The microprocessor was the key element in this evolution, however. It is a general purpose, programmable, integrated circuit of several thousand transistors, produced on a single chip of silicone only a few millimeters in area. It is equivalent to the central processor unit of a conventional computer.

A comparison of the size and capabilities of the Fairchild F-8 microprocessor with the ENIAC (Electronic Numerical Integrator and Computer) illustrates the tremendous reduction in size and increase in computing capabilities of computers in the span of three decades. The ENIAC was 3000 cubic feet in size, the Fairchild F-8 0.011 cubic feet, over 300,000 times smaller. The ENIAC required 56,000 times more power, 140,000 watts to 2.5 watts. Yet, both had an ROM (Read Only Memory) capability of 16K bits. The Fairchild F-8 was over

20 times faster, contained about the same number of transistors as the ENIAC did tubes but 5000 times fewer capacitors, and was 10,000 times more reliable. There was a decided weight differential also; ENIAC weighed 30 tons, the Fairchild F-8 less than 1 pound.

The development of microprocessors altered the entire market potential of sophisticated electronic equipment and expanded greatly the range of people affected by and using information processing equipment.

These and other major breakthroughs in electronic and information-systems technology have the potential for altering the future more than any other technical development in the past. Developments in information systems will continue to alter the way we structure our daily existence, our economy, and even how we perceive ourselves and our society. For instance, electronic controls based on microprocessors are used in the continued development of automated factories, phototypesetting systems, air-route traffic-control systems, telecommunication terminals for business and industry, and computerized sales registers combined with real time inventory control, among others. These developments, together with the extension and adoption of microelectronics into all aspects of life, as well as the basic systems of production, transportation,

and communication technology, form the core of the central technological achievements in the mid-twentieth century. During this period, information systems based on microelectronics and microprocessors became an integral part of society to such an extent that the society could not function without them.

The Nature of Technical Means

The new environment, created by humankind, is a technological environment--an environment in many respects increasingly hostile to its creators. There is a new awareness about technical means, ranging from optimism to deep uncertainty and anxiety about humankind's ability to control and use technical means for human fulfillment rather than destruction. Life today depends on forms of technical means that most people do not understand and which operate within a social structure they are unable to control.

What is the answer? Abandon our technical means? Hardly likely. Redirect the technical means? Opt for a different kind of technical means more compatible with the nature of humankind and with the natural environment?

The latter option implies new levels of awareness about technical means and its impact on individuals

and society. Most people are aware they are living in a world of great physical changes made possible by an ever-expanding technical means. Some people have become concerned about the meaning of these changes and their impact on freedom, society, political institutions, and life styles.

The option of creating different forms of technical means, of redirecting the means to be more compatible with the nature of humankind and the natural environment, implies the exercise of control over the type of technical means selected for the future. And control implies knowledge and understanding of the behavior of human and technical systems and their interrelationships.

It would seem, therefore, that if the potential for altering the future of humankind does exist, then there is a need to study the nature and characteristics of the means which can make a new and more compatible future possible.

A Knowledge Society

Parallel with the establishment of information systems as the primary characteristic of twentieth-century technology was the change of society, particularly in the Western world, from rural agricultural and industrial societies dependent on unskilled and

semi-skilled workers applying manual skill to their tasks, to what Peter Drucker has called a knowledge society with "knowledge workers." Knowledge, according to Drucker and others, became a primary industry in the mid-twentieth century and brought about significant changes in the perception of human potential, technological change, and society.

Rather than knowledge being the province of institutions of education and isolated scholars, knowledge became the concern of business and industry. It is estimated that over one-half of the gross national product of the United States in the 1980s will be generated by knowledge industries. The knowledge industry includes those enterprises concerned not only with the creation of knowledge but also with the distribution, processing, application, and assessment of knowledge. The development of information systems with high-volume capabilities for acquisition, storage, processing, and dissemination was a significant event in the shift to a knowledge-based society. This shift brought about significant changes in the nature of society, such as a shift of power from ownership of property or other political criteria to knowledge, as well as a shift in the character of the knowledge itself.

The change in character gave primacy to theoretical knowledge over empiricism and the use of knowledge to create new knowledge. Rather than knowledge being valued for its own sake, it became valued for its potential as a new source of production. This idea was probably first developed with the rationalization of production and the commitment by men such as John Wilkinson, Joseph Whitworth, and others to use their knowledge to create better tools and thus higher quality production. Others, including Frederic W. Taylor and Henry Ford, contributed to the evolution by the analysis of knowledge and information to improve work flow.

Early efforts were focused on individual tasks and plants. Later efforts incorporated total systems, to the extent that the structure and classification of knowledge incorporated the characteristics of completeness, objectivity, and interdependence. The shift also incorporated the belief that knowledge was not a passive element but an active element, something that had value and could be used to create new futures. The focus of the knowledge industry shifted the perspective to the acquisition and use of knowledge to solve real human problems.

Knowledge and Technical Means

The creation and operation of technical systems have increasingly become more dependent on organized, theoretical, and structured knowledge than on the practical intuitive know-how and folk knowledge of the past.

The tools created in the twentieth century are of a different order than the tools created during the period of industrialization. The tools of industrialism extended the physical capacity of human beings; the tools of today are of a broader and more encompassing order. They are systemic and require an entirely new order of thinking. Examples include the application of electronic and other devices with high levels of discrimination to the tasks of sensing and controlling machine operations formerly done by human operators. When the entire system is totally integrated and internally governed by electro-mechanical devices, the process is said to be automated. With the advent of the computer and the capability to provide analog control of individual machines and digital control for coordination and control with feedback and self-correcting capability to an entire factory system, cybernetics came into being. With cybernetics came a new philosophy about the potential of human beings and society.

Significant changes in the way people perceived themselves and society resulted from developments in communication. Whereas at the beginning of the twentieth century, information was distributed by letters, newspapers and point-to-point electrical systems such as telegraph and telephone, succeeding developments in radio, television, and satellites with broadcast potential established new relationships between humankind and the environment. In the process a new form of symbiosis was discovered, a symbiosis which has the potential for creating a more ecologically sound and humane future for all of humankind. The new symbiosis involves a shift in the relationship of people to their technical means, from one of mechanical or electronic extensions of human physical attributes to one of organic interdependence. The new symbiosis utilises new sensing devices to probe the innermost reaches of the cells of life, as well as to monitor the biosphere by use of satellites, creating, for the first time, the prospect of comprehending the critical variables which affect life and living on earth (McHale, p. 58).

This evolution of technical means and the knowledge base is creating a new form of technical means which is intellectual rather than machine oriented. The intellectual technical means substitutes algorithms

(problem-solving rules) for intuitive judgments. If the challenge of the last part of the twentieth century is managing the "organized complexity" of large-scale systems with large numbers of interacting variables, then the new intellectual based technical means will be a necessary tool.

In dealing with problems on a local or global scale, the approach is to determine a rational action and an appropriate means for achieving the desired goal. Fields such as information theory, game theory, decision theory, utility theory, and linear programming are part of the new intellectual technology developed to aid in problem solving and decision making. The primary tool of the new intellectual based technical means is the computer which can be programmed by using selected algorithms.

All too often there is confusion between knowledge and information. Information can exist without being organized into a systematic form, knowledge cannot. The organization and integration of information about technical systems into conceptual, systematic, and transmittable form which provides the user with the means to predict the behavior of these systems is technical knowledge. This form of knowledge requires integration of a high order. Knowledge is created

when facts, data or information are related to other facts, data or information in a conceptual whole which provides an understanding of the functioning or behavior of a system at some order of complexity.

A technological society must, by its nature, be a knowledge society. Knowledge is necessary to create tools, machines, techniques and technical systems; it is also necessary to determine the nature and characteristics of the systems required to support a given social system. Knowledge is also necessary to determine the characteristics of social systems most conducive to the enhancement of the quality of life. The latter requires extensive knowledge about people as individuals, as members of groups, and the functioning of individuals and groups in a societal context. The new knowledge, to be valid, should enable persons to obtain more intimate truths about themselves as individuals, about the society in which they live as an organic, person-related entity, and about the relations between technical systems, people, and the environment. The ultimate goal is the attainment of an order of knowledge that enables the conceptualization of the behavior of the humankind-technology-society-environment equation. This is a highly complex, difficult and necessary task in any society, but particularly

in a society where technological change is a primary characteristic. In a changing society traditional modes of behavior are often self-defeating, detrimental and sometimes destructive.

The creation of new technical means directed toward predetermined human ends requires new forms of knowledge often different from knowledge organized in traditional disciplines. Unfortunately, traditional disciplines focus on unitary fields of inquiry, whereas the future will require the integration of traditional disciplines and the creation of new disciplines and modes of inquiry which focus on the problems associated with the design and development of new technical and social systems. The modes of the new disciplines will emphasize the utilization of information about all aspects of life and living for the creation of knowledge for the solution of human and societal problems.

The commitment of deciding the future by choice rather than chance developed when people realized that they and their societies need not conform to new systems brought about by new technical developments in which they had no voice. Instead of a <u>free technology</u> and a <u>directed society</u>, the question becomes, "Why not a <u>free society</u> and a <u>directed technology</u>?" If the latter is chosen, then the new knowledge structures will differ

greatly from present ones as will the goals of education, whether the concern is for the preparation of a future citizen or the preparation of a future worker.

Intellectual Factors

One other factor becomes evident in examining the nature of knowledge and technical means. The character of thinking involved in creating a philosophical position, a new religion, or an alternate form of government is different from the character of thinking involved in technological activities. Thinking, when involved in technological activities, is problem specific and environmentally specific, concerned with efficiency and the relationship of elements in the behavior of a total system. The latter engages the question of "why" one system is more effective than another as well as "how" the system works. The goal is predictability of outcome and performance.

Technological knowledge, therefore, is more than knowing about material manifestations such as tools and machines. It also involves the ability to combine many diverse factors and elements into a working whole in order to reach some preconceived end. Not only is it necessary "to know" certain facts about the way things function, it is also necessary to be able to analyze

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the relationships and synthesize new relationships, thus creating new inventions, innovations, or designs. The nature of the thought processes involved in this hierarchy of modes of thinking is unique or at least central to the generation of technological knowledge.

Knowledge for technological work is, therefore, about both knowing that thus and so is true in a given context and also in knowing how to accomplish a given preconceived end. Technical means effectively combines the universe of knowing with the universe of doing. As such, it is a unique intellectual enterprise. Ordinarily, most analyses of knowledge and technical means focus only on things and techniques. By doing so, they omit the entire intellectual component of technological work. The origin of things and the process which brings things into being is with human beings and their intellect, not in the things.

Technology and Science

The relationship between technology and science requires investigation if the confusion between them is to be clarified and a more adequate understanding of technology attained.

The primary reason for the interest in determining the differences and relationships is because of the

impact of technical means and technological change on people and society. Those who make decisions about the future--elected representatives, corporate managers, and people in general--are concerned about impacts of technical means and science on society and individuals.

Most writers conclude that there are differences between technology and science. And most writers, to a greater or lesser degree, attempt to show relationships with few definitive conclusions. This stems from at least two factors: the background, experience, and value context of the writer; and the changing nature of both technology and science. Many writers discuss differences or relationships based on seventeenth- or eighteenth-century technology and science, and then project their findings to the twentieth century. Also, there seems to exist, among those who write about the issues, a decided proscience perspective. Some hold that technological advance comes from the practical application of scientific discovery. They prepare elaborate lineage studies to show that certain scientific events occurred before certain technological events, therefore establishing that science precedes technology.

Unfortunately, as other investigators have shown, the linkages between events in technology and science

are not proved. In fact, until the middle of the nineteenth century there were remarkably few connections between science and technology.

The attempt to build a case by looking backward and placing a higher order of value on contemplation rather than on action has delayed the probability of gaining true insight into the nature of the differences, relationships or new structures.

This is because an entirely new discipline has evolved that is neither technology or science as commonly defined, but which has new aims and goals and new modes of thinking and doing. A change in the perception of technology and science has taken place. Whereas scientists once rejected any consideration of practical problems, and technologists rejected theory, we find a new discipline emerging composed of those who combine theory and practice in the solution of technical, human, and social problems. The new discipline is best described as a systematic social technology, concerned with the basic problems of life and living, such as food, clothing, shelter, communication, and transportation, among others.

This change in thinking provides an essential insight into the problem of the technology-science relationship throughout history. Just as present

societies perceive technology and science differently and create a new systematic social technology, so did past societies perceive technology and science differently. If a true perception of technology or science at a given time in history is to be attained, then it is necessary to structure the perspective from the ideologies and social contexts of that era, not the present. Why? Because there has been a continual evolution in meaning of the words technology and science. In different cultures and at different periods in history, there were different meanings for the words, as there are today.

Differentiating between technology and science today is best accomplished, according to Otto Mayr, by focusing discussions on several categories. They include (1) the nature of the knowledge structure, (2) the type of work and activities engaged in by the people who do the work, (3) the motivation (ideologies) of the people who engage in technology or science, and (4) the aims and goals toward which the activities are directed.

None of the criteria will differentiate if used singly. The problem of differentiation between technology and science, both historically and in contemporary society, is too complex and too confused by past attempts to rely on single variables. It may be that a clear,

concise differentiation will never be attained. However, a perspective on the problem can be provided.

The history of science and scientific ideas has been better served than has the history of technology, primarily because of the experience and background of those who have written about technology and science.

The literary scene has been dominated by those with a humanist tradition. Traditionally, humanists have shown a widespread disregard for technology's role in human affairs. The same has been true of historians who were concerned more with "great movements headed by kings, generals, or businessmen." When they wrote about the events of technology and science, they emphasized that with which they were most familiar, traditional science and philosophical ideas. To the traditional humanist and historian, technology was merely the application of scientific laws and theories.

Much of the evidence to make the case of the importance of science to technology or the unity of technology and science has been overstated, according to Melvin Kranzberg (1968, p. 27). It depends on what he describes as "chronological fallacy," the belief that because one event preceded another chronologically, the events were connected causally. The most common connections, often prepared in chart form to show the

relationships between prior science and later technology are the development of the steam engine and the transistor. The 1500-year period from Heron's experiments with expanding steam to James Watts' improvement of Newcomen's atmospheric steam engine and the development of the transistor in the 1940s are cited to illustrate the decreasing period of time from scientific discovery to technological development. The problem with these comparisons is that the development of the steam engine did not begin with Heron, but with Newcomen and his predecessors, and that the steam engine was a technological development, not a scientific one. The development of the steam engine came about because of a problem with mine drainage. Therefore, historians such as Kranzberg conclude that "new technology grows mostly out of old technology, not out of science," and "scientists concern themselves chiefly with the problem posed by science, not by technology."

J. M. Langrish and others also question the chronology methodology (p. 35). They offer four reasons:

1. Difficulty in defining the scientific discovery on which a technological application is based. Different time intervals are assigned by different authors for given innovations.

2. Possible biases in selection of innovations and events due to absence of standard selection procedures. "It is in fact not difficult to produce sets of examples which show time-lags increasing substantially during the last hundred years or so."
3. Impossibility of observing anything other than a short time-lag for recent discoveries. "Discoveries made in the last few years may be exploited in the future, and such cases are of necessity excluded from consideration."
4. Many cases have negative time-lags. Many times technological advance comes before the scientific advances that help to make them understandable such as was the case with the first synthetic rubber and plastics which were produced prior to the development of polymer chemistry.

There are relationships, but of a different order than commonly believed. According to Kranzberg, the relationship between technology and science can best be described as a disunity rather than a unity, and as two distinct orders of activity engaged in by human beings with an on-going dialectic between them (1968, p. 30). The relationship is more dependent on the

situation or problem than on doctrine. It is a pragmatic relationship, free of formal protocol, and exists in specific contexts which vary according to the situation (1968, pp. 32-33). Rather than one relationship there are many, with the initial entree and dialectic determined by the situation and the problem.

Case after case can be cited illustrating the fallacy of the "science precedes technology" doctrine, even in fields such as chemical technology, aeronautics, and electricity. The attempt to link the production of sal ammoniac to scientific theories has not been proved (Schofield). The creation and development of the aeroplane by Orville and Wilbur Wright was not dependent on science but on technology and technological modes of thinking and doing. The difference between a technological activity and a scientific activity, whether in studying questions about sal ammoniac production or flight, is distinct, particularly with reference to goals, nature of the problem, problem setting and scope.

Technological Activity	Scientific Activity
Goal: to create the human capacity to do; to create new and useful products, devices, machines, or systems.	Goal: to obtain fundamental understanding of nature and the physical universe.
Problem: complex and interrelated problems involving design, materials, energy, information, and control. Many variables, both technical and social. Involves total system design.	Problem: small, highly detailed, manageable problems designed to contribute to a body of information that may provide the base for generalizable theories.

Setting: situated directly in the social milieu.	Setting: isolated from requirement of meeting direct social needs.
Scope: Restricted	Scope: Not restricted

The goals of the discipline concern the purposes of the activity while scope concerns the narrowness or breadth of the activity. If the goal of an activity is set by some specific human problem, the nature of activity would be technological; whereas if the goal of the activity is based on curiosity and interest in finding basic generalizable theories, the activity would be scientific. Caution should be exercised in making too simplistic a separation. Abstract theories can be used for the solution of practical problems as the solution of practical problems often leads to abstract theories.

Technology is situated in a human and social context from which the goals which direct the activities of the discipline are derived and from which the scope of the field on inquiry is determined. In the process of development, the goals and scope of technology have been altered as new potential presented new choices. Today, rather than focusing on problems concerned with specific tools for a specific application in a given craft within a limited social environment, the goals and scope of technological problems include inquiry

into total systems and their interrelatedness, technically and socially. In this context the perception of technology changes, as does the reason for studying the new discipline.

It is also important to recognize that whereas scientific activity is concerned primarily with what is and the nature and structure of the physical universe, technological activity is concerned with what can be. In determining "What can be?" values and the process of valuing become paramount. Therefore, rather than focusing on discrete elements, those involved in technological activities necessarily must be concerned with totalities, with systems and the behavior of systems. It is here that the greatest difference ecists between the various perceptions of scientific and technological activity. Whereas those involved in science are concerned with nature, the question with which technologists are concerned must be about human beings, the physical world and society. It is one kind of question to determine the nature of some physical phenomenon. It is quite a different series of questions when it comes to collecting new data related to a specific problem, analyzing the data, creating a design, testing the design, and implementing the proposed solution in a human context.

Technological Literacy

The goal of any formal education program should be literate students. What does it mean to be technologically literate?

If the question was what does it mean to be literate in French or Russian, the reply would be that the student should be able to speak, read and write in the French or Russian language, implying a knowledge and understanding of the words, symbols, syntax and structure of the language as well as the ability to perform using the language. It also implies a knowledge and understanding of the history and culture of the countries where the language is primary. A similar situation exists with respect to technological literacy.

Today, we live in a complex, interelated, computerized technical society. The first requirement of a technological society is that it is an educated society, an enlightened and informed society. The best way to focus on the centrality of this rather obvious point is to remember that each and every person on earth is a member of the spaceship earth. The more sophisticated the spaceship and the more crew members, the greater the task of educating people to manage and control it for the safety and security of all.

It would seem that each crew member must have a level of literacy about the functioning of our complex ship so that they will be able to make informed decisions and will not become frustrated and alienated by its technical nature. This requires citizens knowledgeable about the characteristics, capabilities and limitations of the technological environment of the spaceship and the impact of their choices about the technical design of the spaceship on their future and the future of unborn generations.

The creation and use of technical means is a large complex area of human intellectual activity which has evolved over the centuries and has had great social and psychological impact, but is little understood by society. And as critical as the understanding of technical systems is, as a basis for determining public policy and the management and control of technological systems, little effort has been made by public education to address the issue of technological literacy.

A large portion of our population live in total ignorance about technical systems, their creation, capabilities, operations and limitations. Most live with perpetuated myths and folk knowledge that detracts from true understanding. However, many people are becoming aware of the significance of the problems.

For instance, concern has been increasing about the issue of the form of technological literacy. It has become a critical issue because of the problems of society resulting from what is called an industrialized or corporate technical system. Institutionalized or public education has always focused on literacy and training for the corporate or industrial need. These training programs are called vocational, occupational and career education. The education system has become linked more closely to the needs of business and industry through these programs. The type of literacy required by this approach to literacy is job specific, less complex and seldom transferrable to the new and evolving technical systems.

The other form of technological literacy focuses on the role of the individual in a free society as a citizen of a community, state, nation and world who functions in many roles and is responsible for the proper functioning of the spaceship today and for the long-term sustainable future. This is a much more complex level of technological literacy than the literacy required to obtain and sustain a job in a corporate enterprise.

There are many ways of structuring a program of technological literacy. An economist would focus on

the production function, an engineer on the technical, an anthropologist on the cultural and a sociologist on the social. None of these approaches is sufficient to structure a program of technological literacy today. What is needed is the focus of the technologist who is concerned with the study of the creation and use of technical means--tools, machines, techniques, technical systems--and the behavior of technological systems in relation to people, their societies, the environment and the civilization process. The technological literacy of today and tomorrow must be based on a unifying, integrating study of the behavior of natural, technical and social systems.

This requires a new knowledge base incorporating the study of humankind; other cultures; social systems and the behavior of systems; decision making processes; change processes; the history and development of technical means; goals and values in human societies; technological assessment; technological forecasting; the interrelation of systems and the behavior and control of systems, both technical and social; the invention and innovation process and new technologies and technological systems including energy systems, transportation systems, communication systems and production systems; alternative and future social and technological systems; and

the process for designing new technologies and new social and technical skills, among others.

The new literacy must also incorporate the concepts, relationships, and consequences of technical means together with knowledge and know-how in the appropriate selection and design of technical means and the process of transfer and adoption of new means into society with the least impact on people, the social system or the environment.

Thus, the focus of the new literacy is on the process of creating, using and assessing technical means at several levels. These levels range from a knowledge of the function and use of tools in the broadest sense of the term, to the design of products produced by people using tools, and the use, relation and impact of the products on people, society and/or the environment.

Most efforts concerned with technological literacy have focused on knowing about and using tools or on assessing the impact or effects of technical means. Both are restricted efforts and fail to attain a true literacy. All too often it has been assumed that a casual encounter with tools or the reading of a book or two on technological and social change will produce a technologically literate person. This surface

treatment fails to comprehend the complexity and interrelatedness of the task. True literacy will require a sustained effort over time to develop knowledge and understanding of the abstract concepts upon which the technical world has been created and functions. This level of understanding cannot be gained from hearing or reading about inventions and technical systems. What is required is direct and sustained involvement in the processes of the technologist. The mind must be prepared to be capable of observing and establishing differences, similarities and relationships. Human beings are not only perceptual beings, they are also conceptual. They are capable of learning and using technological modes of thought. Harold Halfin, in his study of the intellectual processes or methods of inquiry used by technologists, identified seventeen distinct processes. The processes are defined as "those functional or intellectual skills which are the random or ordered methods, strategies, or operations used by a technologist to accumulate knowledge about an artifact or to solve a technological problem" (Halfin).

1. Defining the Problem or Opportunity Operationally
2. Observing
3. Analyzing
4. Visualizing
5. Computing
6. Communicating

7. Measuring
8. Predicting
9. Questioning and Hypothesizing
10. Interpreting Data
11. Constructing Models and Prototypes
12. Experimenting
13. Testing
14. Designing
15. Modeling
16. Creating
17. Managing (p. 207)

A significant part of the literacy issue is language. Language is not just a means of communicating thoughts, ideas, concepts or technical information, it also structures the way people perceive themselves and how they act and function. Being technologically literate requires that the individual be conversant in several technical languages including the symbolic languages of the various systems.

Finally, to be technologically literate requires a knowledge and understanding of systems.

Technological Systems

Technological systems are composed of elements that are related and which interact in some way. Everything exists in relation to other elements within an immediate and total environment. This means that there is some context within which an element, particle, person, tool, event, action or some other part of a system, acts and

is acted upon. Perceiving the dynamics of a system requires the identification of some central theme, function or behavior, whether the concern is with the composition and behavior of a given material or of an electronic communication system.

First steps in comprehending a system often involve classification, either at the micro or macro levels. Classifying is the process of ordering and organizing that which is observed about component elements or parts. By classifying or ordering the elements of an on-going dynamic event, a beginning is made in the understanding of the behavior of the element in relation to other elements.

There are different types of classification systems designed for different purposes. Some merely group like objects or elements, as is done in the Dewey decimal or Library of Congress systems for classifying books, the Department of Commerce system for classifying industries, or the Department of Labor system for classifying occupations. These might be referred to as static systems.

Taxonomic analysis is another way to classify the component elements of a system. A taxonomy orders elements according to a central theme, a hierarchy, and relationships.

Certain universal technological endeavors exist in all societies at some level of sophistication; they include the means of producing artifacts, transporting goods and services, and transmitting information. Each of these systems can be classified and analyzed as subsystems according to function, activity, or problem category. Examples include categories such as manufacturing, constructing and processing, or terrestrial, marine, air and space systems, and systems of information, transmission, storage and retrieval. To be technologically literate, a knowledge and understanding of the evolution, structure and behavior of these systems is essential.

The Study of Technology

Access to Tools*

The design of an education system to develop a level of technological literacy in all citizens is a complex task. It is, however, a necessary task in a democratic society.

The belief that human beings attain their highest level of human attainment in a free society and that participatory democracy is the best form of government presupposes that citizens must participate in decisions

*Tools in the sense used in this section refer to all devices from the most simple to the highly complex which are used by society to produce goods and services; transmit, store or retrieve information; and transport goods and services; together with the know-how of their use.

concerning the design, development, and use of technical systems. Participatory democracy in a society with more than a primitive order of technical means requires participatory technology. One without the other will not work.

Participation in social or technical decisions requires social and technical knowledge and access to social and technical tools.

These are the preconditions if citizens are to again become part of the process with a sense of intelligent participation and not alienation. The challenge to education brought about by the random development of technical means demands major alterations for one primary reason. The characteristics of a society based on a high order of technical means alter the questions with respect to error and failure. Failure in a complex, modern society is of far greater consequence than in earlier societies.

In earlier times the technical means was not as powerful, dependency on multiple subsystems not as great. If systems were disturbed they returned to equilibrium in a relatively short period of time and damage to human beings and the environment was limited. Not so with respect to the technical systems of the twentieth century. Yet, as dependent as the survival of society

is on the efficient functioning of highly complex technical systems, we find that today the great masses of people are denied access to the tools. The tools of our technical systems have become the property of experts and are under the control of specialists. Thus, the control of the evolution of technical means and society becomes the province of select specialists, none of whom have the responsibility or mandate to be concerned about social purpose and total systems.

If citizens are to regain their freedom and obtain control of their destinies, then they must become involved in the study of technology and gain access to the tools. Dependency on common sense and the folk knowledge of yesterday will not suffice. The technical means of today with its sophisticated tools and knowledge requires disciplined and systematic study, from both a technical standpoint and a social-cultural perspective.

Most citizens have never had the opportunity for the disciplined and systematic study of these systems. Even the technical experts are limited in their understanding. They generally know about and understand the physical forces and principles which provide stereophonic sound, linear induction motors and color photography. Those who create these devices know about and can control these devices. But the issue is not the control of a

single device; the issue is the understanding and control of the behavior of technological systems as a major component of our social system and as a critical factor of cultural change and disruption within society.

The education of citizens for participation in the management of society for human purposes concerns not only the study and comprehension of the behavior of the various technical elements and the tools associated with these elements, but also the study of the behavior of total systems and the social/cultural effects within the total system. The concern would be with the dynamics of the system. The focus would be on what each element does within the system, not what a thing is. The goal of education would be to provide citizens with a means to gain knowledge, to gain control, and thereby mastery over the tools for human purposes.

Unfortunately, education efforts with respect to the study of technology have been narrowly directed, for the most part, toward the preparation of individuals for jobs and specialized roles in society rather than the preparation of self-governing citizens. Also, it has become evident that the new and expanding knowledge base of technology has transcended most educators, and the competence of the average citizen. Many educators have treated the study of technology as something apart

from the daily affairs of citizens and the responsibility of public education. By doing so they have effectively turned the control of a powerful tool over to a regime of experts and denied their students access to the very knowledge and tools so vital to the processes of creating, managing, regulating, and directing technical means for human purposes. Educators often view technology as an "object" and not as a "subject," as something "out there" not really important to education for life and living and thus imappropriate for study. The technical means of society seems to be an abstract created by some individuals which exists outside the sphere of the awareness of educators.

Because of this the education system has muted the awareness of citizens of their ignorance of technology and pursued the policy of machine tooling citizens into marketable commodities in narrow specialities.

The education system creates what Arthur Koestler calls an "urban barbarian" by denying students access to knowledge and tools and limiting their interest in and awareness about technology. Citizens are placed in the position of being effectively shaped and controlled by those in command of the tools and knowledge of the new technologies. Also, the comprehension of the behavior of total systems is voided and technology becomes less and less responsive to citizens and human purposes.

The issue seems to be one for which education, as a social institution, has not developed successful alternatives. Most education programs have focused on the past, the here and now, and on meeting rather specific vocational needs. What is required is a new mentality, a different way of perceiving society and technology. All citizens should be involved in determining the questions and finding the answers, and they should be prepared for participation in the process with adequate knowledge and tools for the task. It means a comprehension of the concept of system and the understanding of the interrelatedness of the elements of a system, i.e., everything affects everything else.

The goal of education should be to provide individuals with the means to find order in a complex global society and to attain the knowledge, skills, tools, attitudes, and values required to participate fully in the management and operation of society.

Without access to tools and knowledge of technological systems, citizens have effectively lost control of their technology. They have become totally dependent on technical means but ignorant about them. To alter this course will require the study of technology by all citizens so they become conversant in the language of technological systems and can comprehend the basic concepts of the dynamics of interrelated systems for all levels of society.

Because of the essential nature of this aspect of citizen education the study of technology must be a component of formal education. The study of technology fulfills the criteria of the "Rule of Irretrievable Loss" formulated by Dick Netzer. The rule is stated simply. "Students should be taught on a compulsory or universal basis, only those things that large proportions of them will never learn unless exposed to the material at the stage in the education process in question, and which it is important that most people passing through that stage do learn" (p. 37).

Technological literacy is a category of education that meets this test and will require attention at all levels of education.

A Curriculum Structure

There are numerous ways to approach the design of an education system which incorporates the study of technology as one of the central themes. All approaches require some form of conceptual structure that organizes the components into a meaningful system showing relationships. An analysis of Figure 1 will indicate that, as a minimum, any curriculum design proposing to teach about technology should include the study of the four systems shown--ideological, sociological, technological

and ecological--and the interrelation of these systems.

In addition to a structure which organizes components into a meaningful system showing relationships, there is need for a structure which illustrates the dynamics of the processes of the system. The participatory processes in which people are involved as they pursue the design of technological systems to serve social purposes are shown in Figure 2. The first diagram answers the question of what to study, while the second diagram illustrates the dynamics of the content by showing the relationships among the systems--ideological, sociological and technological--and the processes involved in the evolution of the systems and society. Three critical processes are involved--valuing, enabling, and assessing.

Finally, the study of technology requires a structure which identifies the primary elements of technological systems and their relationships as a means for deriving programs of study designed to understand the content of the many elements and relationships of technological systems. The matrix of Figures 3 and 4 illustrates an approach for the identification of <u>structure</u> and <u>content</u> for the study of technology.

There are three dimensions to the matrix. These consist of (1) <u>components</u>, which operate in certain

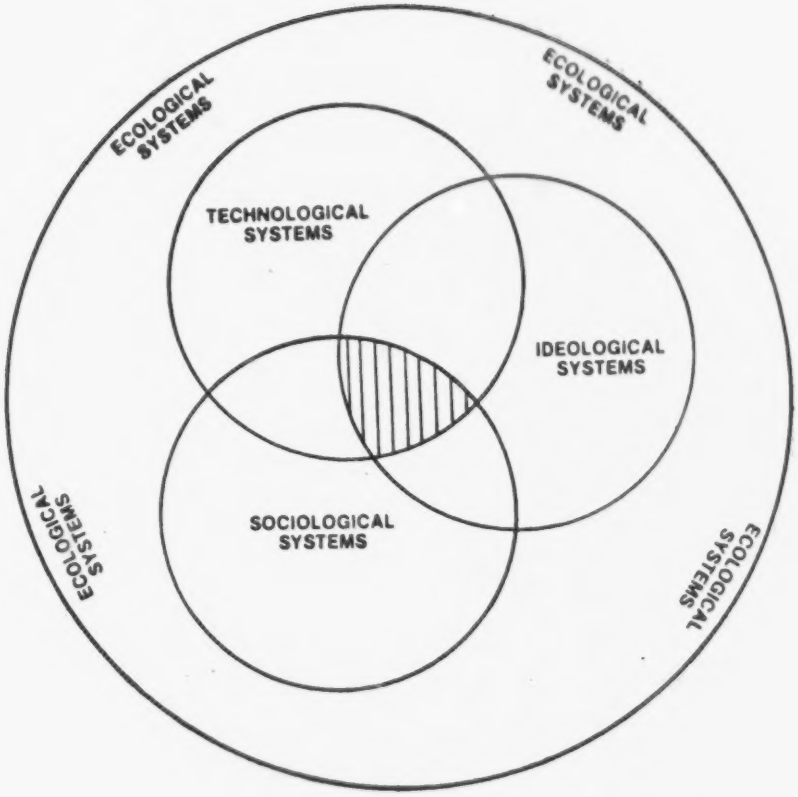

Figure 1. The interrelationship of systems--technological, sociological, ideological and ecological.

(2) contexts, at various levels of (3) complexity. There are both technical components and social components. Technical components consist of resources, materials, tools, machines, energy, power and information. Social components consist of human elements including work skills, intellectual processes, occupations, environmental relationships, and organization and management of technical systems, among others.

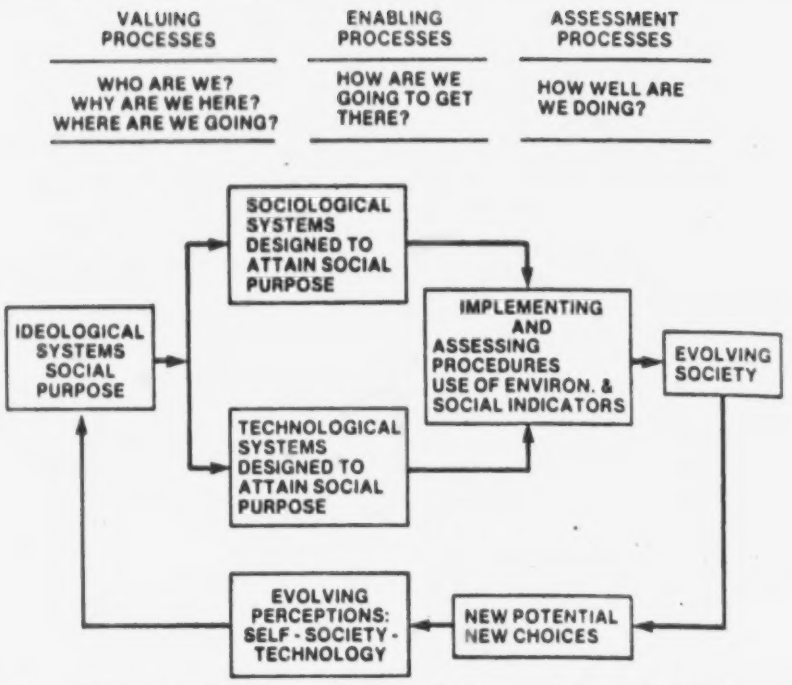
VALUING PROCESSES
WHO ARE WE?
WHY ARE WE HERE?
WHERE ARE WE GOING?
ENABLING PROCESSES
HOW ARE WE GOING TO GET THERE?
ASSESSMENT PROCESSES
HOW WELL ARE WE DOING?
SOCIOLOGICAL SYSTEMS DESIGNED TO ATTAIN SOCIAL PURPOSE
IDEOLOGICAL SYSTEMS SOCIAL PURPOSE
IMPLEMENTING AND ASSESSING PROCEDURES USE OF ENVIRON. & SOCIAL INDICATORS
EVOLVING SOCIETY
TECHNOLOGICAL SYSTEMS DESIGNED TO ATTAIN SOCIAL PURPOSE
EVOLVING PERCEPTIONS: SELF - SOCIETY - TECHNOLOGY
NEW POTENTIAL NEW CHOICES

Figure 2. The evolution and relationship of technological systems and social purpose.

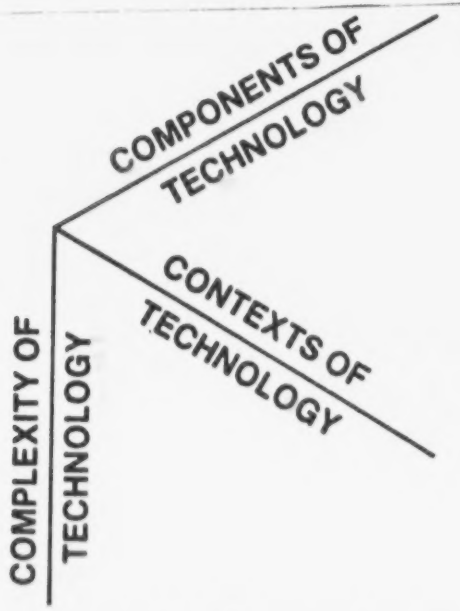

Figure 3. The study of technology--elements of an infrastructure.

These vary depending on people and the structure of the sociological and ideological systems to which a given technical system relates and the ecological system in which it exists.

The various components are structured and used by people in different ways in three interrelated dynamic contexts, communication, production, and transportation systems. These systems exist in all cultures regardless of the level of sophistication of the culture. The relationship of components and contexts is illustrated in Figure 4.

The evolution of technological systems is illustrated by the third axis of the matrix labeled complexity. The design of the matrix provides a means to illustrate that technological systems have evolved from early tool making, through the craft era, to the power and machine period of industrialization, to the atomic and cybernetic stage of the last half of the twentieth century. Continual evolution is indicated by the word future and the extension of the axis.

The structures illustrated provide a means to organize a program for the study of technology which recognizes the necessity of learning not only about systems and their relationships, but the facts, concepts and intellectual processes of the subsystems and numerous

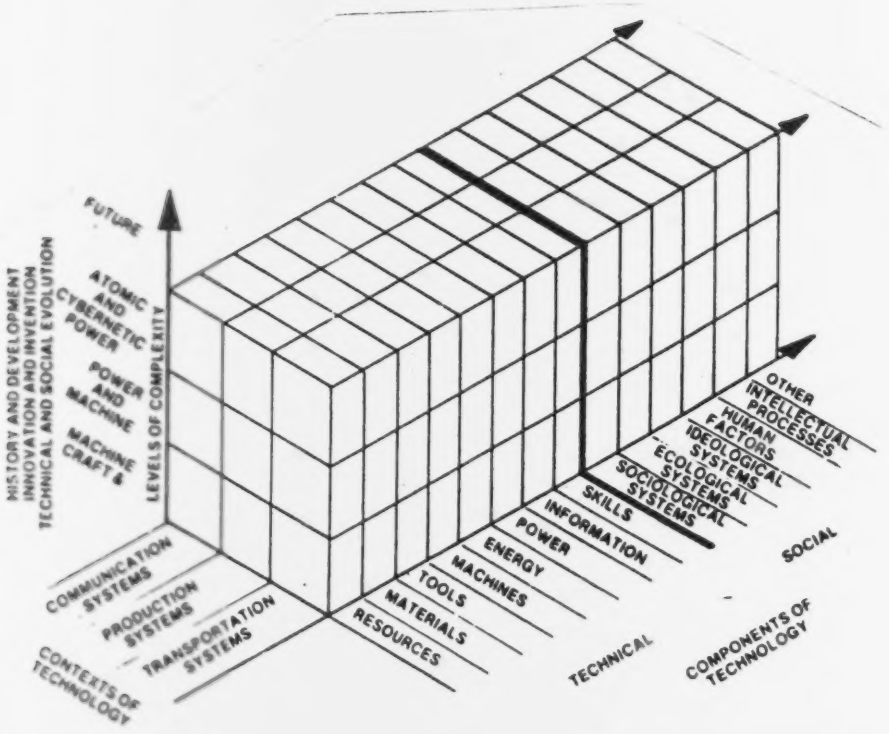

Figure 4. The study of technology--infrastructure.

components from a historical, contemporary and future perspective as well. The matrix implies very clearly that it is not possible to study technology without becoming involved with technical knowledge and technical systems and their elements and operation. The same is true for those who would propose to study technology without becoming involved with human beings, social knowledge and social systems. Such approaches will be abortive and interefere with the development of the kind of education programs required to return the control of technology to people for human purposes.

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